



# Nationwide Lightning Climatology

By  
William R. Schaub, Jr.



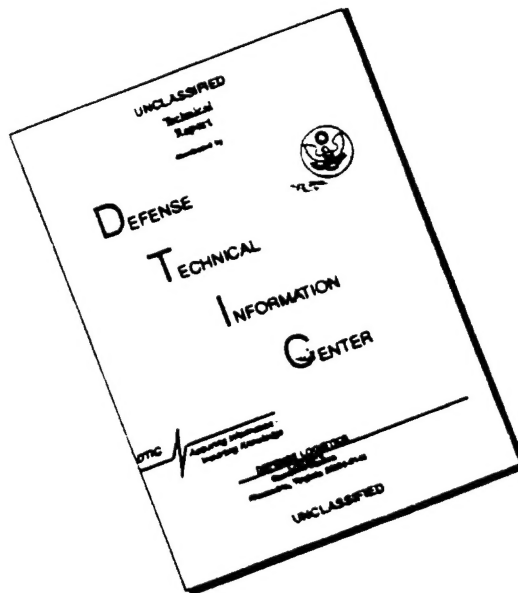
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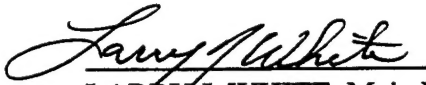
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## PREFACE

This technical note documents results of AFCCC Project 911013, completed by AFCCC's Simulation and Techniques Branch (AFCCC/SYT). The project analysts were Mr William R. Schaub, Jr. and Capt Brian M. Bjornson.

The original customer was the Air Force Systems Command, Directorate of Weather at Andrews AFB, Md. Following Air Force major command restructuring, the new customer became the 645th Weather Squadron at Wright-Patterson AFB, Ohio.

The customer requested a lightning climatology for the continental United States (CONUS) to enhance their support to acquisition customers by determining equipment test locations with high or low probabilities of lightning strikes. One particular program supported was the C-17 program.

A lightning climatology for the CONUS was developed from a database of cloud-to-ground lightning strikes that occurred from March through October during 1986-90. The data was organized using the Northern Hemispheric polar-stereographic quarter-mesh grid system employed at the Air Force Global Weather Central at Offutt AFB, Neb. In that grid system, the prime meridian is at 80 degrees West which makes the west coast of the United States appear tilted upward in relation to the east coast. As shown in Figure 5, the grid length on the earth's surface varies with latitude. From south to north over the United States (e.g., 25 to 50 degrees North latitude), the whole-mesh grid length increases from about 160 nautical miles to nearly 200 nautical miles. Summarized data for each grid point was used to produce a graphics program of the lightning climatology.

The personal computer graphics program enables the user to display bar graphs of the diurnal and monthly variations in the average hourly lightning strikes for eight regions over the CONUS; regional and CONUS isopleth analyses of the average hourly strikes; and a table of average hourly strikes for each region by month.

Analysis of the lightning climatology showed that the patterns of lightning strikes compared favorably with known preferred locations and times of thunderstorm development. AFCCC recommends use of the lightning climatology as another tool for planning and forecasting purposes.

The author extends special thanks to Amn Kenneth G. Weston and MSgt Robert Pena who produced the lightning graphics program.

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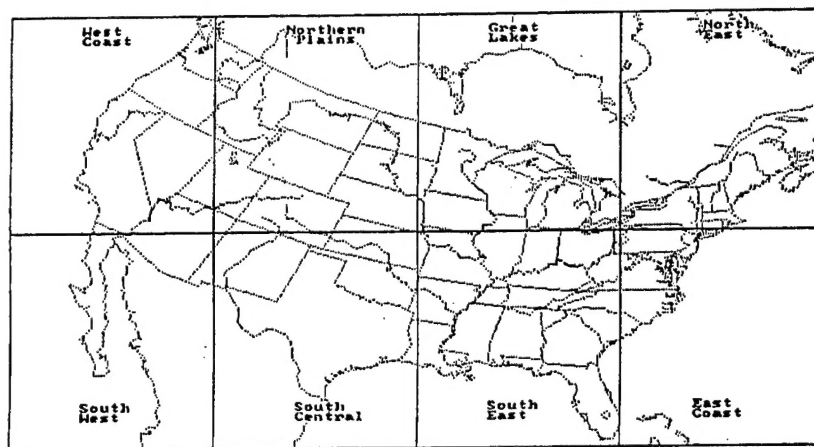
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## Chapter 1

### INTRODUCTION

**1.1 Background.** The 645th Weather Squadron (645 WS) provides meteorological support to a wide variety of customers. As an example, they provide weather information to their acquisition customers by determining equipment test locations that have high or low probabilities of lightning strikes. The C-17 is another system supported by the 645th WS. To enhance their customer support, the 645th WS agreed to take over testing of a nationwide lightning climatology originally requested from AFCCC by the Air Force Systems Command, Directorate of Weather.

AFCCC produced a lightning climatology for the continental United States (CONUS) from a database of cloud-to-ground (CG) lightning strikes that occurred during 1986-90. AFCCC recommended a microcomputer graphics program to display the lightning climatology for the CONUS or by regions in bar graphs, tables, and isopleth analyses. This enabled staff meteorologists at the 645th WS to visualize the climatology and customize studies for their customers. Figure-1 shows the CONUS and eight regions used to develop and display the climatology.



**Figure-1.** CONUS regions used for lightning climatology.

**1.2 Related Studies.** There have been many studies to determine the average number of thunderstorm days to identify preferred regions for thunderstorm development. An early work by the World Meteorological Organization (WMO, 1956) provided worldwide isopleth analyses of the mean number of thunderstorm days. Even then it was noted that a better representation of thunderstorm activity would have been possible if lightning-flash observations had been available. Later, Changery (1981) produced a comprehensive climatology of mean monthly and annual thunderstorms for the United States. His work was based on 10 to 30 years of record for individual thunderstorm beginning and ending times at 450 primary weather stations that took observations 24

hours a day. Both the WMO (1956) climatology and that of Changery (1981) showed that on an annual average the greatest number of thunderstorms occur over Florida and northern parts of Arizona and New Mexico. In 1984, MacGorman, et. al., used an empirical equation that relates CG lightning-strike density to thunderstorm duration, and the thunderstorm duration data from Changery (1981), to obtain a CG lightning-strike climatology for the United States. The annual mean lightning-strike density patterns agreed well with the thunderstorm duration patterns. Recently, Changnon (1993) used CG lightning-strike data gathered within 11 nautical miles of 63 stations across the United States during 1986-89 to produce a lightning climatology. His work



## CHAPTER 1

showed that on an annual average the greatest number of CG lightning strikes occurred over Florida and the Central Midwest.

**1.3 Analysis Procedure.** As discussed in Chapter 2, observations of CG lightning strikes that occurred over the United States and near its borders during March through October from 1986-90 were used to develop the nationwide lightning climatology. Data for eight regions covering the area of interest was organized in a grid system that provided an overall horizontal resolution of 40 to 50 nautical miles for the summarized lightning-strike data. Details of the grid system are given in Chapter 3, along with the methods used to grid and summarize the data. Also in Chapter 3, an analysis of the minimum peak current field for all strikes in the area of interest showed that most values were less than 20 kiloamps, which implies good detection efficiency for the period of record used.

**1.4 Findings.** The lightning-strike climatology appeared consistent with expected diurnal and monthly variations in thunderstorm activity. For example, the nocturnal maximum in lightning strikes for March over the Gulf Stream, about 100 nautical miles east of the South Carolina coast, was clearly depicted and agreed with the WMO (1956) thunderstorm day maximum in that area for March. Also, the monthly increase in the mean number of lightning strikes from lows in March to highs in July and August over the Florida peninsula and the southwest United States followed the trend in mean monthly thunderstorms as seen in the climatology by Changery (1981). When averaged for the entire 8-month period, the nationwide lightning climatology resembled the annual average patterns shown by Changnon (1993), except over the southwest United States where the maximum of lightning strikes in our work was more pronounced.

## Chapter 2

## DATA AND LIMITATIONS

**2.1 Lightning Data.** A 5-year (1986-90) database of proprietary CG lightning-strike data was purchased from GeoMet Data Services (GDS), Inc., in Tucson, Ariz. GDS owns and operates the National Lightning Detection Network (NLDN). During March through October of 1986-90, more than 40 million strikes occurred over the United States and near its borders. The strikes were recorded by lightning direction

finders manufactured by Lightning Location and Protection (LLP), Inc., in Tucson, Ariz. As described by Maier, et. al (1983), the LLP equipment that makes up the NLDN uses triangulation to locate the strikes. Thus, every observation of a CG lightning strike provided by GDS was made by at least two direction finders. Figure-2 shows the NLDN direction finders GDS operated over the CONUS during 1986-90.



**Figure-2.** Lightning direction finder locations. Triangles represent approximate locations of National Lightning Detection Network direction finders that operated over the United States during 1986-90. Scalping shows the nominal range of 215 nautical miles on the fringes of the network. Source: GDS (personal communication).

**2.2 Lightning Data Storage.** The lightning data was stored in AFCCC's Relational Database (DB2) for ease of access. The data was organized in square grid boxes within eight areas that cover the United States as shown in Figure 3. The grid boxes without numbers contain no data. The grid system and (I,J)

coordinates are part of the Northern Hemispheric Whole-Mesh Polar-Stereographic Reference Grid used by the Air Force Global Weather Central (AFGWC) (see Figure 4). An example of a lightning observation in the database is shown below:

YR	MO	DAY	HR	MIN	LATDEC	LONDEC	PCURR	BOX	I	J
89	3	6	21	22	46.718	28.390	98.8	1	1457	2575

The variable definitions are:

YR	year
MO	month
DAY	day
HR	hour (Zulu)
MIN	minutes past the hour
LATDEC	latitude of the lightning strike in decimal degrees
LONDEC	longitude of the lightning strike in decimal degrees
PCURR	the polarity (positive or negative) of the charge lowered to ground by the first return stroke of the flash, and the peak current (in kiloamps) of the first return stroke
BOX	box number (refer to Figure 3) in which the strike occurred
I	I coordinate (calculated from the latitude) of the lightning strike for the 64th-mesh grid
J	J coordinate (calculated from the longitude) of the lightning strike for the 64th-mesh grid

The last three variables (BOX, I,J) were added to the original GDS data by AFCCC

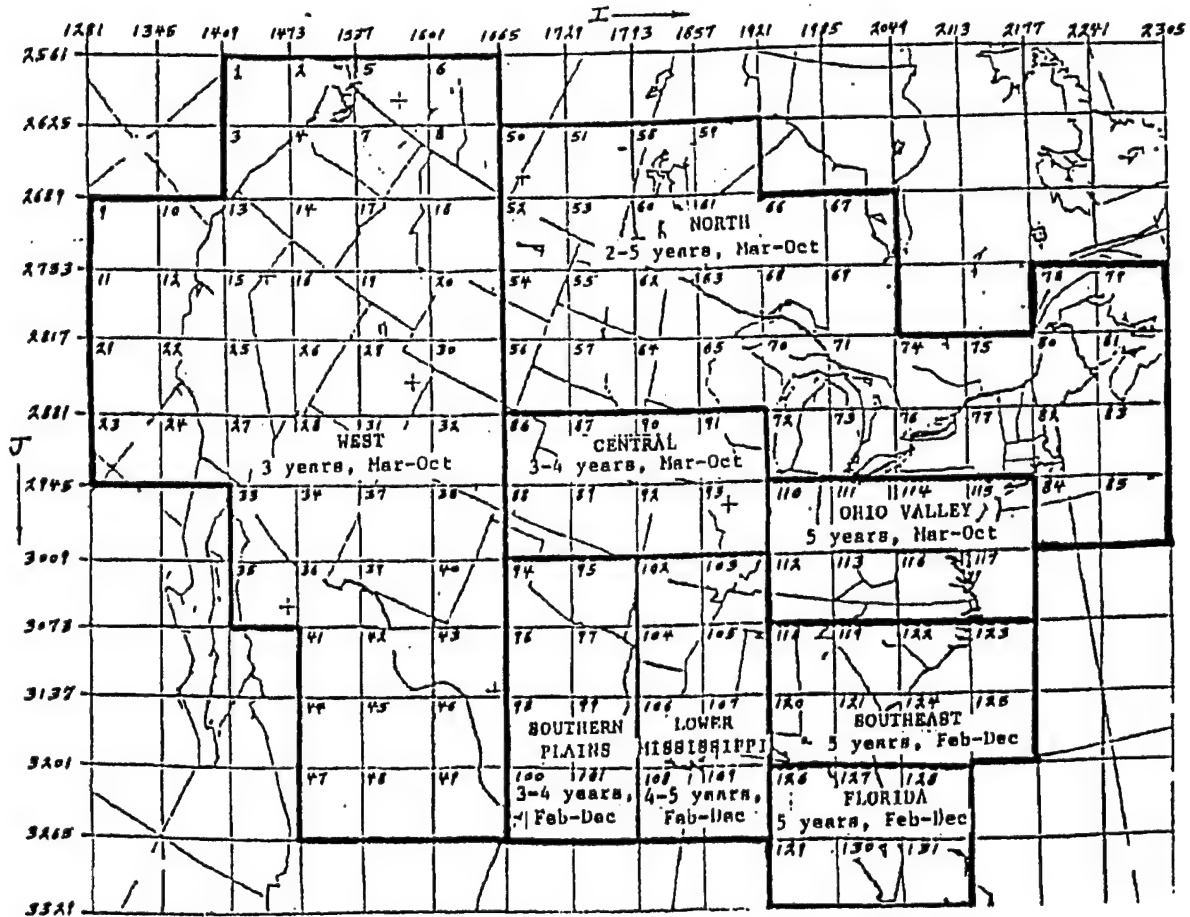
**2.3 LIGHTNING DATA LIMITATIONS.** Most evaluations of CG lightning-strike data quality include discussions of detection efficiency and strike location accuracy. The period of record is also important for a representative database.

**2.3.1 Detection Efficiency.** The detection efficiency is the ratio of the number of CG strikes detected to the number that actually occurred. It is primarily a function of the range or the distance of a strike from the direction finders. MacGorman, et. al. (1985), reported detection efficiencies of 70 to 85 percent for strikes within 54 nautical miles of direction finder networks in Oklahoma and Florida. Over the entire NLDN, a detection efficiency of 70 percent is estimated for strikes within a 215 nautical mile range of direction finders (Orville, et. al, 1990). Beyond that nominal range, strikes are still detected, but at less efficiency. For the present work, Figure 2 shows that during 1986-90 most of the area of interest was

well within the nominal range for a 70 percent lightning detection efficiency.

**2.3.2 Location Accuracy.** Like detection efficiency, the strike location accuracy depends on the range of the strike; but it also depends on the number of direction finders that record the strike, the distance between direction finders, and where the strike occurs in relation to the direction finders (Maier, et. al., 1983). According to GDS, the lightning strike locations are generally accurate to within 1/2 to 2 nautical miles.

**2.3.3 Period of Record.** Over most of the United States, the period of record for the CG lightning-strike data was 5 years, as shown in Figure 3. From discussions with researchers involved in lightning studies, the consensus of opinions was that 3 to 8 years of lightning data are sufficient to produce a representative climatology.



**Figure-3.** Lightning data storage. AFCCC's lightning data for the United States is stored by grid box number within eight areas as shown. The grid system (I, J) coordinates are part of the Northern Hemispheric whole-mesh polar-stereographic grid used by the Air Force Global Weather Central. The (I, J) coordinates shown are for the 64th-mesh grid. The whole-mesh grid boxes without numbers have no data.



## Chapter 3

## METHODOLOGY

**3.1 The Grid System.** As mentioned in Chapter 2, part of the Northern Hemispheric whole-mesh polar-stereographic reference grid in Figure-4 (next page) was used to organize the lightning-strike data. In that grid system, the prime meridian is at 80 degrees west which makes the west coast of the United States appear tilted upward in relation to the east coast. As shown in Figure-5 (see page 9), the grid length on the earth's surface varies with latitude. From south to north over the United States (e.g., 25 to 50 degrees North latitude), the whole-mesh grid length increases from about 160 nautical miles to nearly 200 nautical miles.

**3.2 Lightning Data Preparation.** To assign lightning-strike observations to points in the grid system with a minimum effect on strike location, the (I,J) coordinates for the 64th-mesh grid (labeled in Figure 3) were calculated for each observation from the latitude and longitude location of the strike using equations given by Hoke, et., al. (1985). In the 64th-mesh grid, the grid spacing is about 3 nautical miles over the United States. Thus, any strike location error in the original GDS data may have been increased by as much as 2 nautical miles in this initial gridding

process. After the (I,J) coordinates were calculated, box numbers shown in Figure 5 were assigned to each lightning-strike observation for convenience in locating and summarizing them.

**3.3 Setting the Horizontal Resolution.** For the nationwide lightning climatology, each whole-mesh grid box in Figure 3 was divided into 16 grid boxes (quarter-mesh). The new quarter-mesh grid boxes were numbered and the numbers were assigned to lightning strikes that occurred in them. As a result, the grid length or horizontal resolution of summarized lightning data in this work varies from about 40 to 50 nautical miles (south to north) over the United States.

**3.4 Assigning New Grid Box Numbers.** To illustrate the process of assigning new grid box numbers to lightning-strike observations, an example is shown using whole-mesh grid boxes 1 through 4 in Figure 3. It was necessary first to determine quarter-mesh coordinates ( $I_4, J_4$ ) for each lightning-strike observation from the 64th-mesh coordinates (I,J). Using procedures given by Hoke, et. al. (1985), the (I,J) coordinates were transformed to ( $I_4, J_4$ ) coordinates as follows:

$$I_4 = \text{INT}([(I - \text{ILAT})/\text{IJUNITS}] + 1) \quad (1)$$

$$J_4 = \text{INT}([(J - \text{JLON})/\text{IJUNITS}] + 1) \quad (2)$$

where:

INT = operator that acts to keep only the whole part of the number

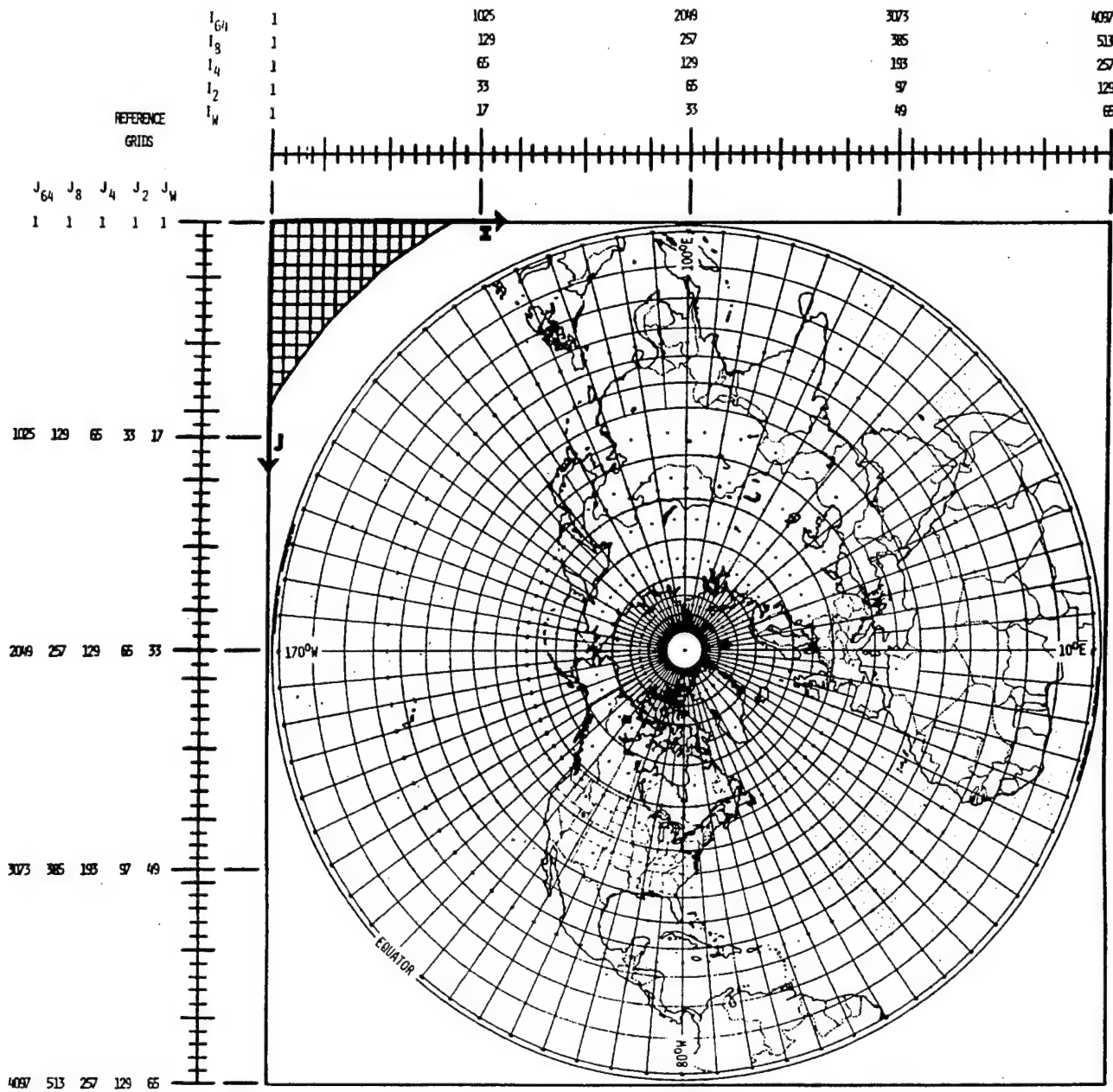
I = 64th-mesh I coordinate of the lightning strike

ILAT = 64th-mesh I coordinate of the upper-left corner of the area (value 1409 at upper-left corner of box 1 in Figure 3)

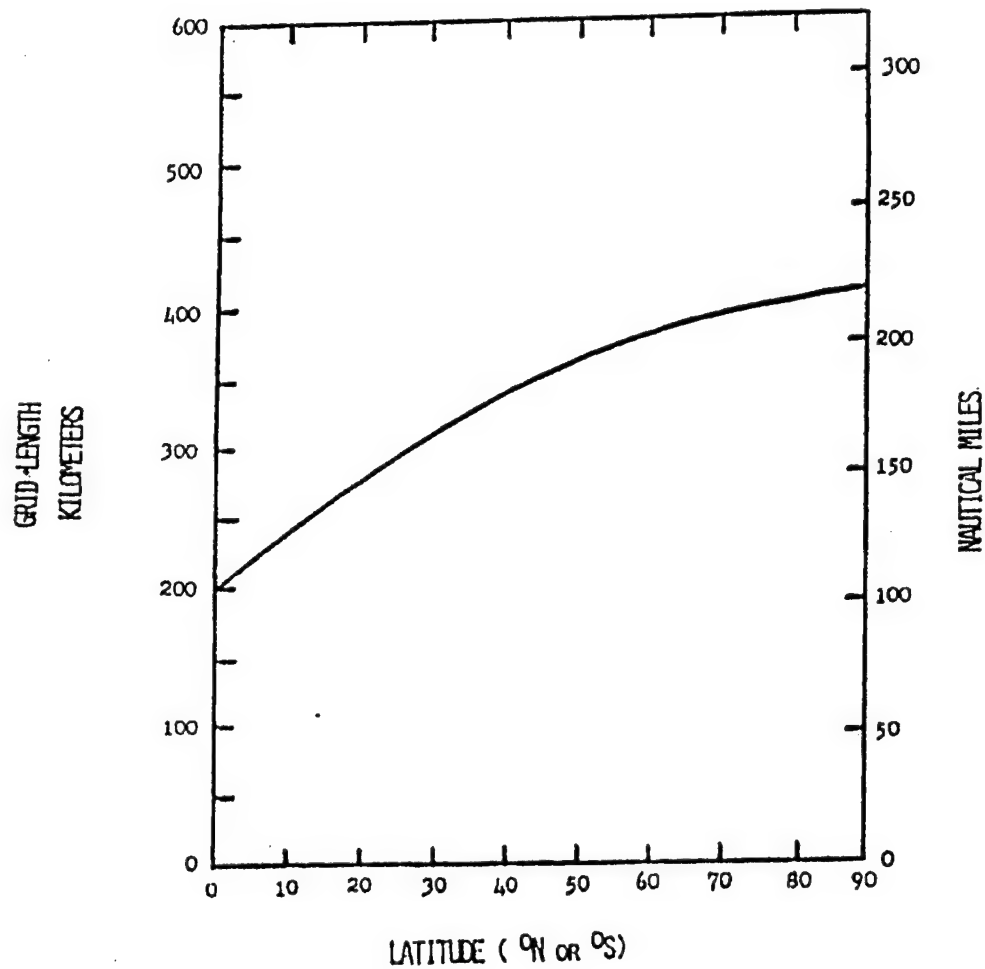
IJUNITS = number of grid boxes in each whole-mesh grid box (16 in this case for quarter-mesh)

J = 64th-mesh J coordinate of the lightning strike

JLON = 64th-mesh J coordinate of the upper-left corner of the area (value 2561 at upper-left corner of box 1 in Figure 3)



**Figure-4.** The Northern Hemispheric whole-mesh polar-stereographic reference grid. The grid spacing is shown in the upper-left corner. The (I, J) indexing convention is also shown. This convention allows for (I, J) labelling of every grid point. The ( $I_w$ ,  $J_w$ ) coordinates represent the whole-mesh grid scale. The ( $I_2$ ,  $J_2$ ) coordinates represent the half-mesh grid, and so on. Source: Hoke, et. al. (1985).



**Figure-5.** The grid length on the earth's surface as a function of latitude. Graph shown is for a whole-mesh grid in a Northern Hemispheric or Southern Hemispheric polar-stereographic projection. Source: Hoke, et. al. (1985).



Lastly, the quarter-mesh grid box number (BOXNUM) for each lightning-strike observation was calculated from the following:

$$\text{BOXNUM} = I_4 + [\text{SQRTBOX} (J_4 - 1)] \quad (3)$$

where SQRTBOX equals 8, the square root of the total number of quarter-mesh grid boxes (4 whole-mesh boxes times 16 quarter-mesh boxes per whole-mesh box). In the example above, the area originally covered by whole-mesh grid boxes 1 through 4 was covered by 64 quarter-mesh grid boxes, starting with number one in the upper-left corner of the area and proceeding left to right, top to bottom, to number 64 at the lower-right corner. The same procedure was applied to the remaining whole-mesh grid boxes over the United States.

**3.5 Lightning Data Summarization.** As sections of each data storage area in Figure-3 were assigned new quarter-mesh grid box numbers, the lightning strikes within each section were sorted by month, hour, and quarter-mesh grid box number. The total number of strikes was obtained for each grid box by month and hour. If strikes were not detected for any month or hour, a value of zero was assigned for purposes of calculating the average number of strikes. The average hourly number of lightning strikes for each grid box was calculated as follows:

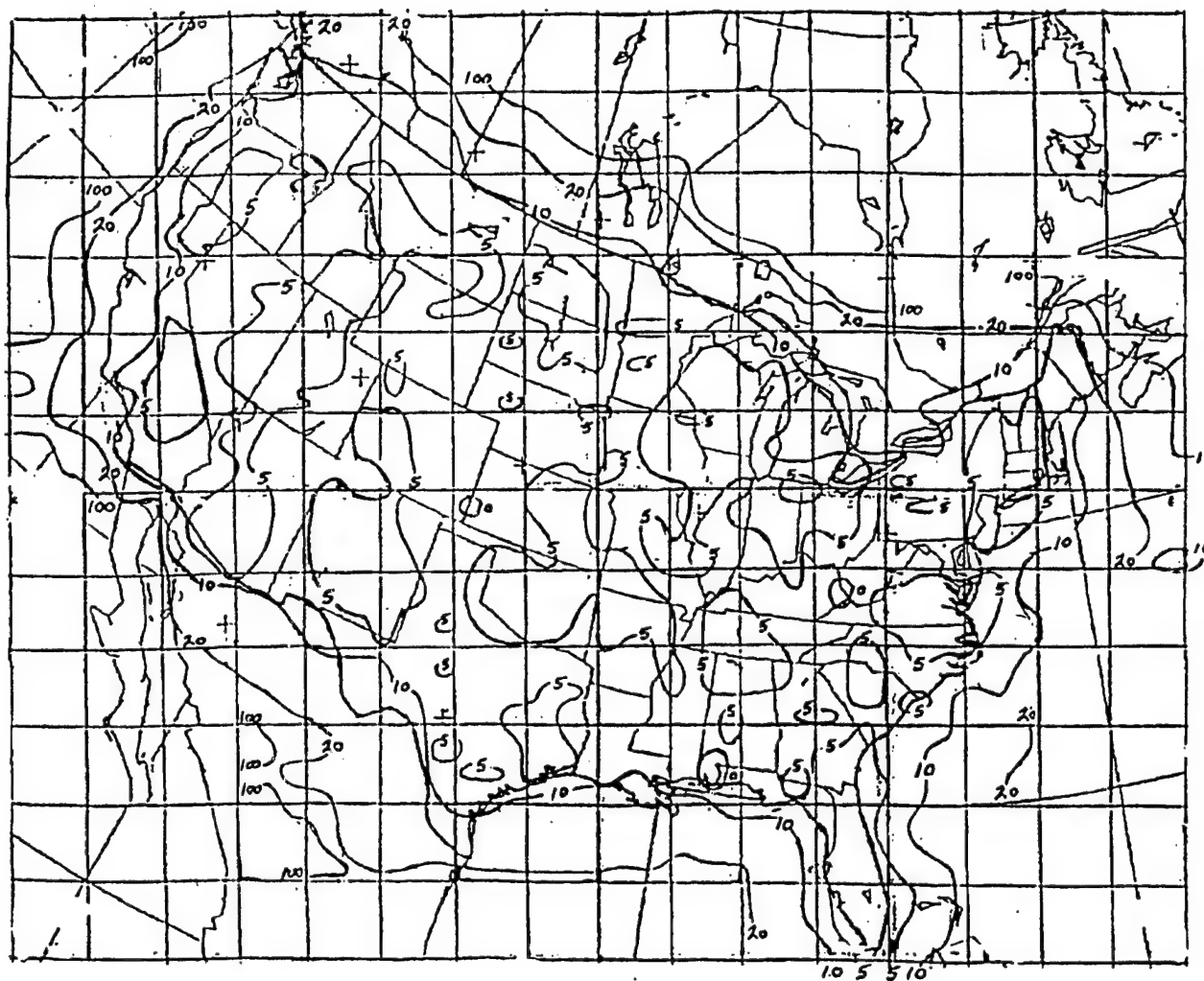
$$\text{Average Hourly Strikes} = \frac{\text{Total Strikes by Month and Hour}}{\text{Years of Record}} \quad (4)$$

For example, if a total of 100 strikes occurred in a grid box for July at 2100Z over a period of 5 years, the average hourly strikes for that box for that month and hour was calculated as  $100/5 = 20$ . In the lightning climatology graphics program discussed in Chapter 4, the average hourly value of 20 strikes was placed at a grid point defined by the upper-left corner of the grid box.

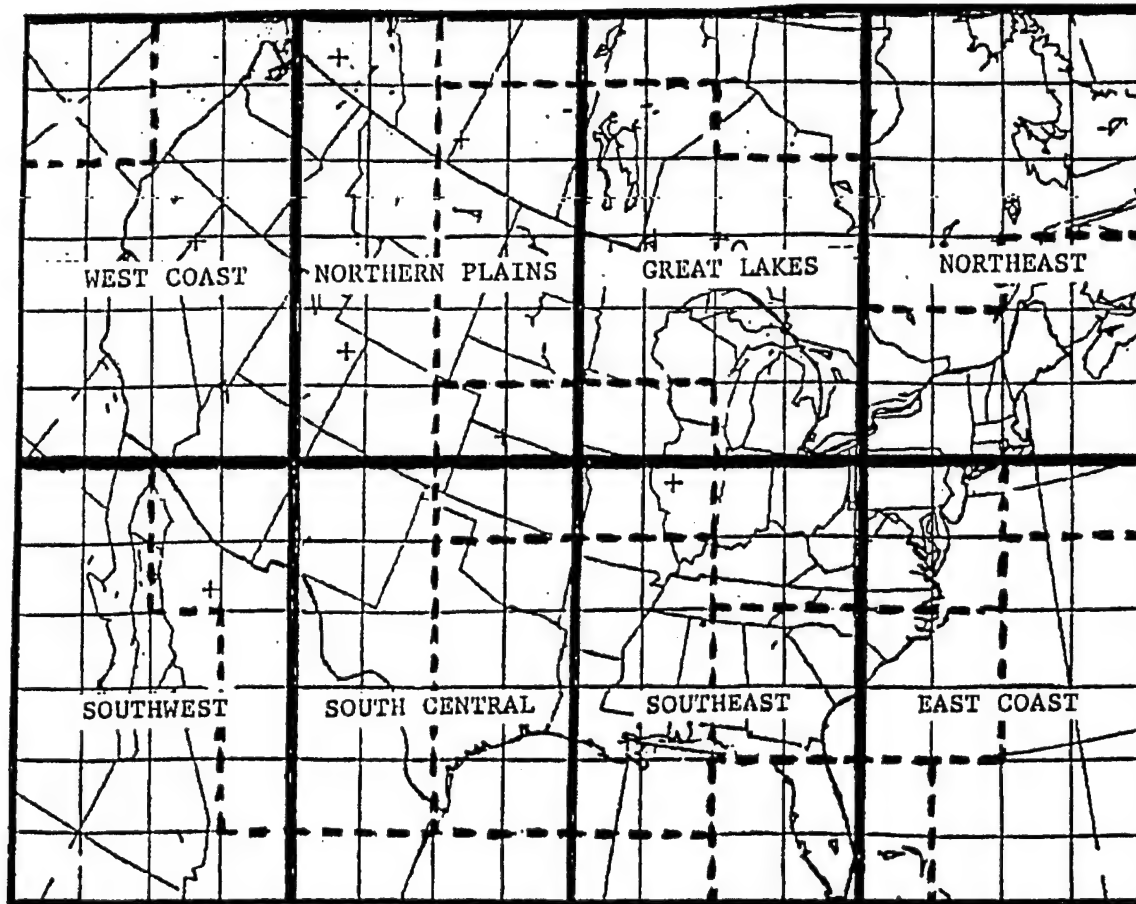
**3.6 Analysis of Minimum Peak Current.** As noted in Chapter 2, each lightning-strike observation contains information on the polarity (positive or negative) and magnitude of the peak current

(kiloamps) of the first return stroke of the CG lightning strike. In an effort to assess the detection efficiency during the period of record in this work, the minimum value of the absolute peak current recorded in each grid box was obtained based on all years, months, and hours. The assumption was that under conditions of good detection efficiency, a network of lightning-strike direction finders should show relatively low values for minimum peak current within the network over a period of years. It was also assumed that as distance from the network increases, higher values of minimum peak current become evident as weaker strikes become less detectable. An isopleth analysis of the minimum peak current field over the area of interest is shown in Figure-6. As expected, the minimum peak current is relatively low (less than 10 kiloamps) over most of the United States and increases outward from the borders. Uman (1987) documented results of several studies on the frequency distributions of first return stroke peak currents for both negative and positive CG lightning strikes. The studies showed that at the 50th percentile the typical peak current is 30 to 35 kiloamps, and that peak current values around 10 to 15 kiloamps occur in about 90 percent of CG lightning strikes. From Figure-6 and estimates by MacGorman, et. al. (1984) and Orville, et. al (1990), it can be concluded that detection efficiency was good (e.g., 70 to 85 percent) over the United States and some distance beyond its borders during the period of record used in the present work. As an approximation, the limit of the 215 nautical mile nominal range for at least 70 percent detection efficiency lies between the 10 and 20 kiloamp contours in Figure-6, when compared with the scalloped area in Figure-2.

**3.7 The Nationwide Grid.** To provide uniform coverage of the United States, the grid in Figure-3 was divided into eight equal parts and named by region as shown in Figure-7. The grid box numbers were rearranged so that each region contained 384 grid boxes with values for the average hourly lightning strikes by month and hour. Due to overlaps of some data storage areas in Figure-3 with the regions in Figure-7, a mixture of periods of record for the summarized lightning data resulted. Therefore, the months of March through October were used for the lightning climatology in all eight regions.



**Figure-6.** Isopleth analysis of the minimum peak current. Contours represent absolute values of minimum peak current in kiloamps. Data is for the period from March through October during 1986-90.



**Figure-7.** The nationwide grid. Regions shown are as in Figure-1. Each whole-mesh grid box shown was divided into 16 square grid boxes to provide a horizontal resolution that varies from 40 to 50 nautical miles (south to north) over the United States. Data storage areas from Figure-3 are superimposed with dashed lines.

## Chapter 4

## LIGHTNING CLIMATOLOGY AND RESULTS

**4.1 The Lightning Graphics Program.** The summarized lightning-strike data was used to produce a microcomputer graphics program to display the nationwide lightning climatology. As described by Weston and Pena (1993), the user-friendly graphics program runs on IBM or compatible 286-based personal computers with the following minimum features: 640KB main memory; MS-DOS Version 3.2 or later; EGA or better graphics; Epson-compatible dot matrix printer for hard copies (upgrades will include HP Laser Jet printer capability); and 3.8MB hard-drive space. The program is not validated to operate under Microsoft Windows, and it will not run from floppy drives. A math coprocessor decreases run time, but is not required.

**4.2 Graphics Displays.** As mentioned in Chapter 3, the lightning graphics program uses the average hourly CG lightning-strike value for a grid box at a grid point defined by the upper-left corner of the box. Also, all hours are shown in Zulu. For consistency, graphic displays throughout the lightning climatology show lightning-strike values that are hourly averages. For example, if a display option allows selection of several months and hours, the number of average hourly lightning-strike values collected in the graphics program is divided by the number of months and hours so that the displayed values are always hourly averages. The displays and input options available in the program include bar graphs, isopleth analyses, and tables as listed below:

- Bar graph of the daily (diurnal) variations of the average hourly lightning strikes within a region. One, several, or all grid boxes in a region may be selected for any combination of months (Mar - Oct).

- Bar graph of the monthly variations of the average hourly lightning strikes. One, several, or all grid boxes in a region may be selected for any hour or combination of hours (0000Z - 2300Z).

- Isopleth analyses of the average hourly lightning strikes for any region for any combination of months and hours.

- Isopleth analyses of the average hourly lightning strikes for the entire United States (all eight regions), also for any combination of months and hours.

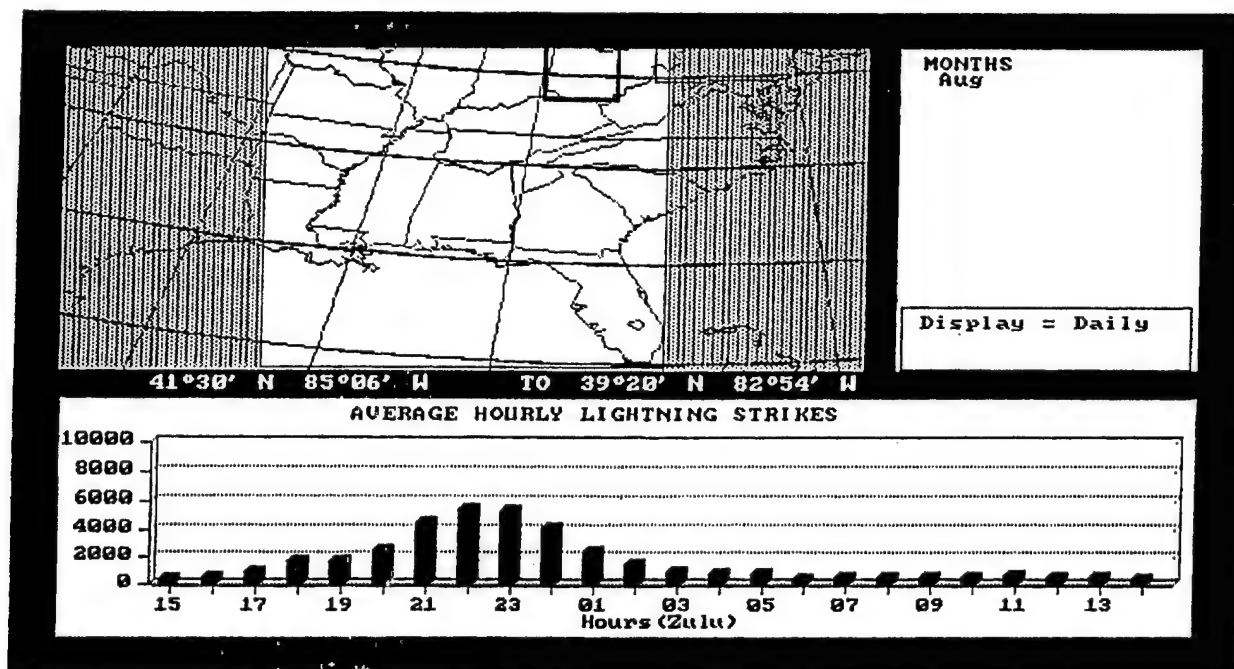
- Table of the average hourly lightning strikes for each region by month for any combination of hours.

If several grid boxes are selected for the bar graph analyses displays, the average hourly lightning strikes for each grid box are added. For example, if four selected grid boxes each had a value of 10, the displayed value in the graphs would be 40 average hourly lightning strikes. In contrast, the isopleth analyses displays provide contours of individual grid box values. For the tables in the last option above, the values shown are the sums of the average hourly lightning strikes for the 384 grid boxes in each region. In the future, an option will be included to enable the user to display the analysis of minimum peak current shown in Figure-6. It should be noted that contour values of isopleth analyses beyond the United States borders may be misleading. At some point beyond the borders, the contours drop off to zero. Obviously that does not always mean that lightning strikes did not occur. The drop off is mostly due to a decrease in detection efficiency of lightning direction finders with increasing distance from the network.

**4.3 Using the Program.** Upon entry into the lightning graphics program, the user must first select a region and an area within the region if bar graphs or regional isopleth analyses are desired. If isopleth analyses for the United States (CONUS) or the table option are desired, they can be selected directly. For bar graphs and regional isopleth analyses, the area selection can be done from the computer keyboard using the cursor (up and down arrows) or by using the mouse in a sweeping motion. The keyboard method works best for selecting small areas. Each time the cursor is moved, the user is provided the cursor location in degrees and minutes of latitude and longitude. After an area or whole region is selected, the latitudes and longitudes of the upper-left and lower-right corners are provided.

**4.4 Illustrative Example.** An example is shown in Figure-8 where a daily bar graph of average hourly lightning strikes for August was selected from an area covering western and central Ohio (seen as small square area in bold lines) in the Southeast region. In the graphics program, the area selected appears shaded for easy recognition. The section to the right of the regional map display contains information on the input options (months and hours) and display type. The bottom section is used to display either daily or monthly bar graphs. Regional or CONUS isopleth analyses and table displays are presented as separate

whole screens. Printed copies are available for all displays. As seen in Figure-8, the regional map is compressed from top to bottom. The distortion is due to fitting the geography of rectangular regions that are taller than they are wide into the area of a computer screen with opposite dimensions. The CONUS isopleth analyses appear normal within the graphics program, but are distorted when printed. The distortion does not affect the accuracy in any case. **NOTE:** Although not seen in printed copies, areas where data was not summarized are shaded gray in the graphics program.

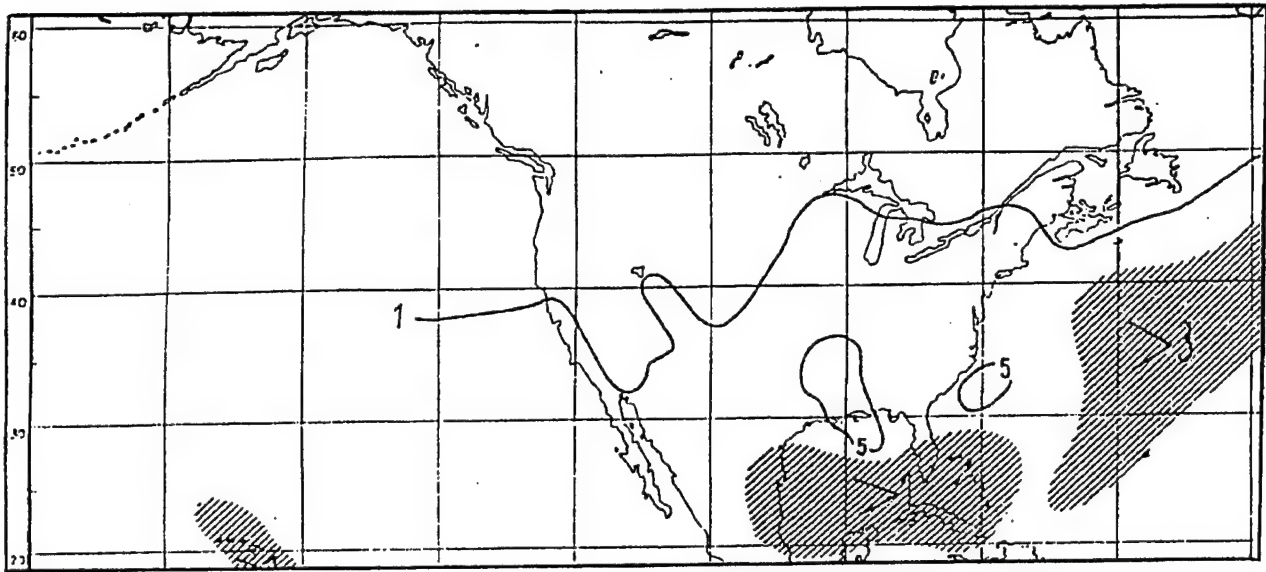


**Figure-8.** Example from the lightning graphics program. Graph of the diurnal variation in the average hourly lightning strikes for Western and Central Ohio (square area within bold lines at the top-right of the region map) for August.

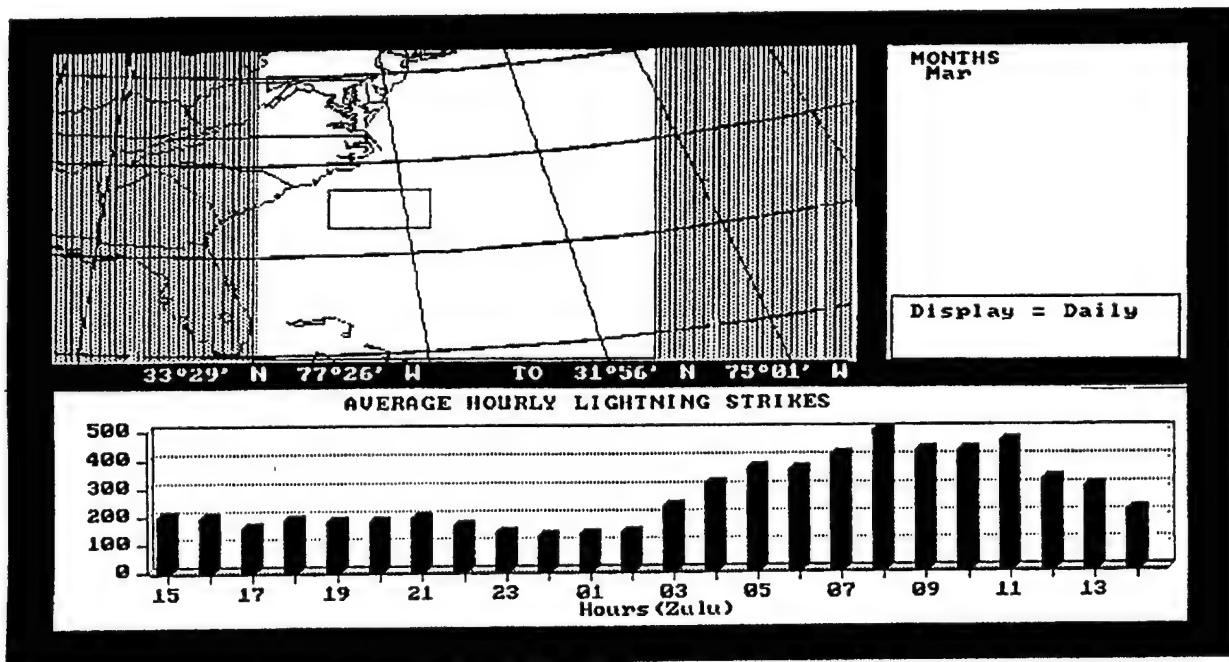
**4.5 Comparison with Other Studies.** In this section, some results from the nationwide lightning climatology are compared with other studies on thunderstorms and lightning strikes. The comparisons show that the nationwide lightning climatology coincides closely with thunderstorm and lightning patterns found by others.

**4.5.1 Diurnal Lightning-Strike Variations.** A typical pattern of diurnal variations was shown in Figure-8

for part of Ohio where most strikes occurred around 2200Z. Similar patterns were evident in other regions over the CONUS. One notable exception occurred over the Gulf Stream off the southeast coast of the CONUS. As shown in Figure-9 from the WMO (1956), an average of five thunderstorm days occurred during March in that area. An analysis of the diurnal lightning-strike pattern (Figure-10) showed that most of the lightning strikes in that area were centered around 0800Z.



**Figure-9.** Average thunderstorm days over North America in March. Source: WMO (1956).

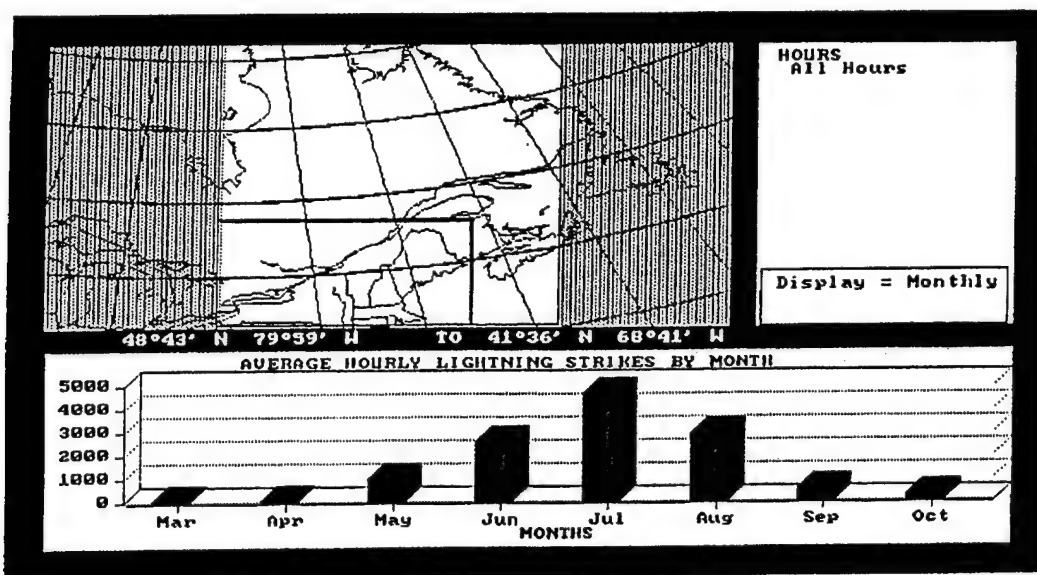


**Figure-10.** Diurnal lightning-strike variations over the Gulf Stream in March. Graph is for rectangular area in center of the region map.

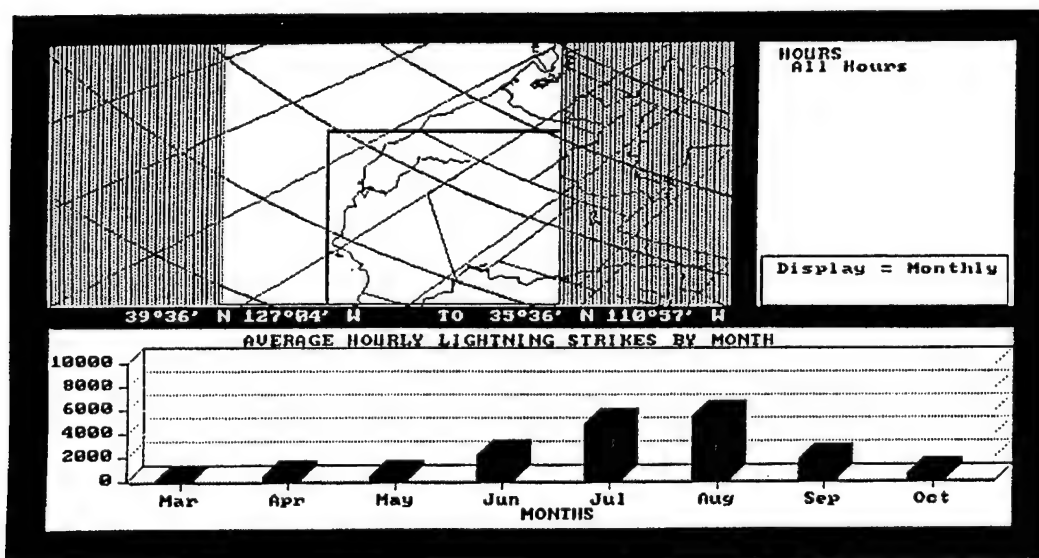


**4.5.2 Monthly Lightning-Strike Variations.** It is well known that across the CONUS most thunderstorms occur during the summer in July and August as shown in the thunderstorm climatology by Changery (1981). Two examples from the nationwide lightning climatology (Figures-11 and -12) show a similar pattern in monthly variations of average hourly lightning strikes. Figure-11 shows that most lightning

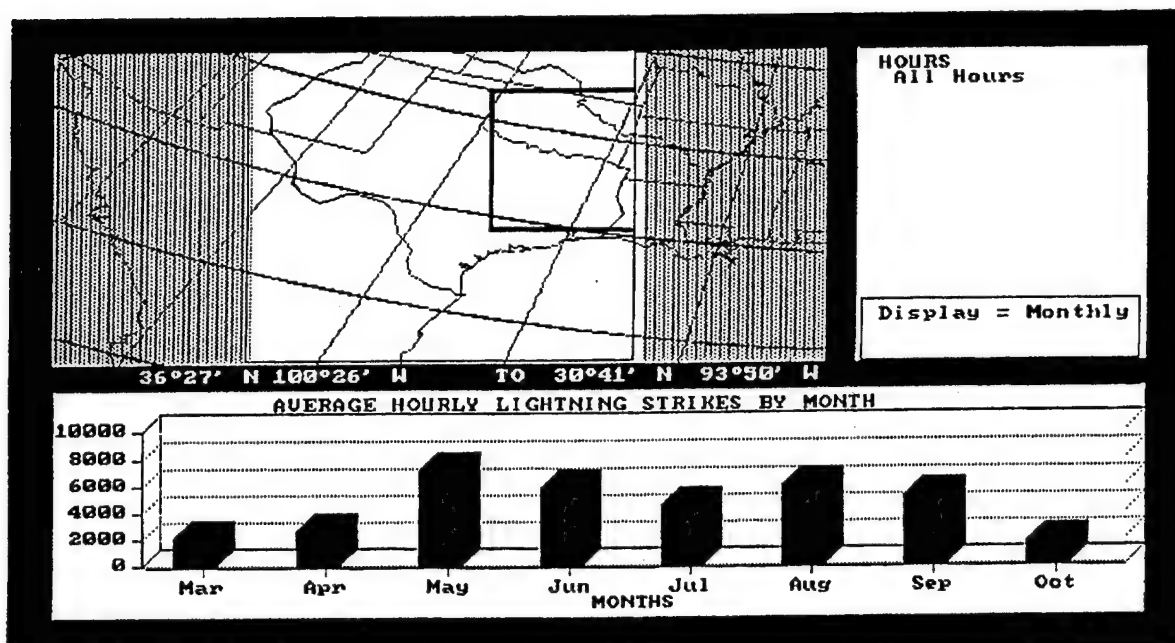
strikes occur over the northeastern CONUS during July based on all hours. Similarly, Figure-12 shows a maximum of strikes over the southwestern CONUS during August. Figure-13 (next page) shows that an exception occurs in the area of Oklahoma and eastern Texas (also seen in Changery, 1981) where the maximum is in May during early summer outbreaks of severe thunderstorms in that area.



**Figure-11.** Monthly lightning-strike variations over the northeastern CONUS. Graph is for rectangular area at bottom of region map.



**Figure-12.** Monthly lightning-strike variations over the southwestern CONUS. Graph is for square area in lower-right part of the region map.

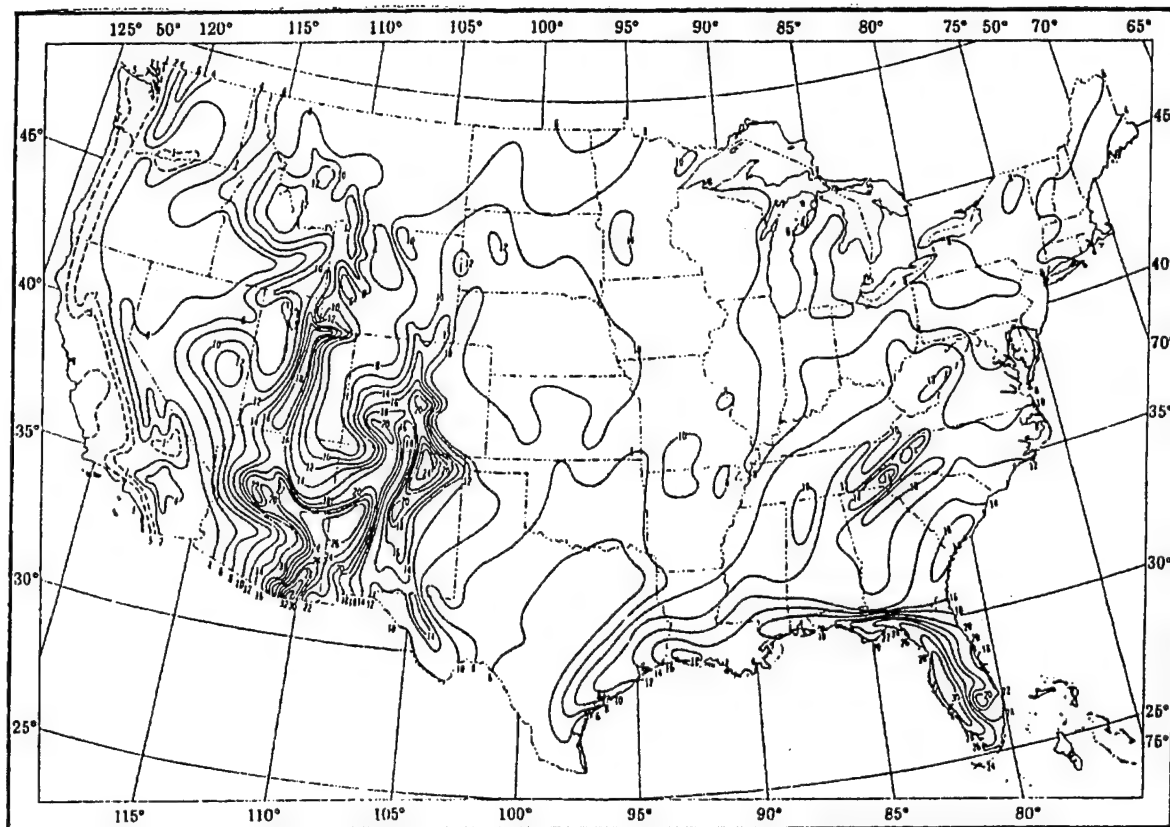


**Figure-13.** Monthly lightning-strike variations over Oklahoma and eastern Texas. Graph is for square area on upper-right side of the region map.

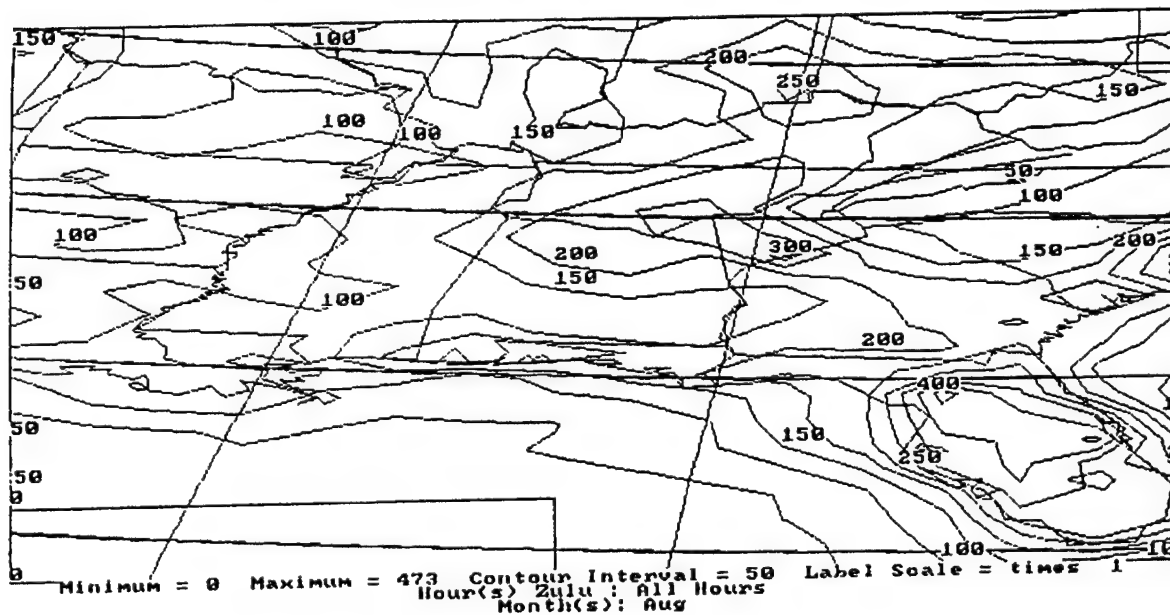
**4.5.3 Regional Lightning-Strike Patterns.** Examples of regional isopleth analyses of the average hourly lightning strikes for specific months were taken from the nationwide lightning climatology to compare with thunderstorm patterns. Figure-14 from Changery (1981) shows the mean number of thunderstorms over the CONUS during August. Obvious maximums exist over the Florida peninsula and southwest CONUS. By comparison, Figures-15 and -16 show contours of the average hourly lightning strikes for August over the southeast and south-central United States, respectively. In Figure-15, the lightning-strike pattern along the western part of Florida that starts from a maximum of 473 average hourly strikes and extends southward corresponds well with the thunderstorm

pattern in Figure-14. Also, the respective patterns are in good agreement over northern Alabama and Georgia. In Figure-16, attention is drawn to the maximum value of 304 average hourly lightning strikes over central Oklahoma. No such concentrated area appears in the thunderstorm pattern in Figure-14. However, there is good agreement between Figures-14 and -16 over northeastern New Mexico where a maximum of 24 occurs in mean thunderstorms, and a secondary maximum of 200 occurs in average hourly lightning strikes. In another example, this time in Nevada (Figure-17), the maximum of 146 average hourly lightning strikes in east-central Nevada corresponds exactly with an area of 12 mean thunderstorms in Figure-14.

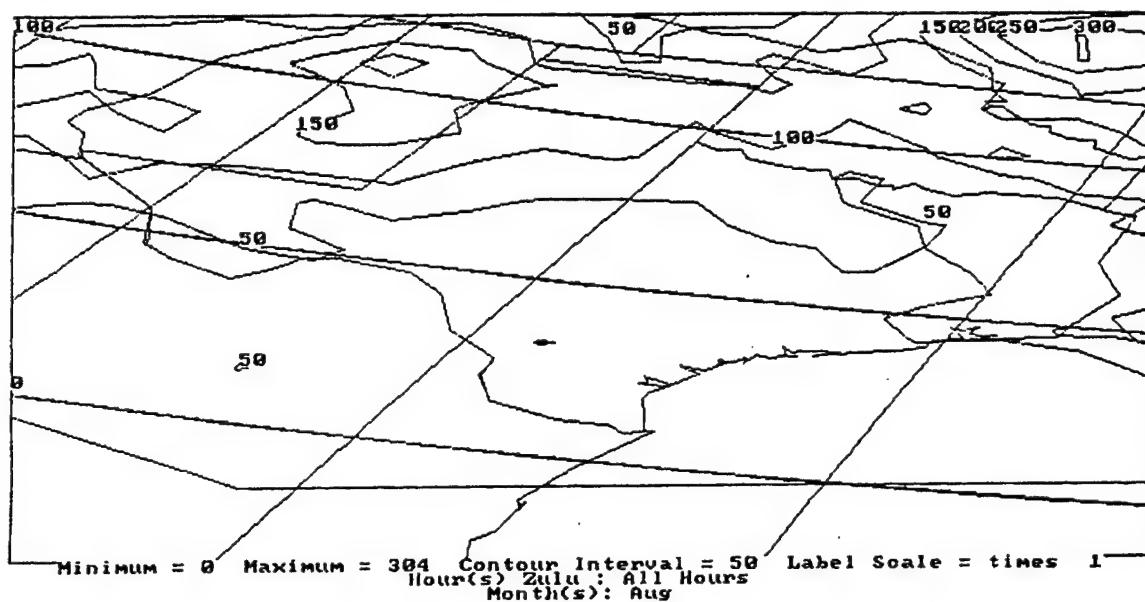




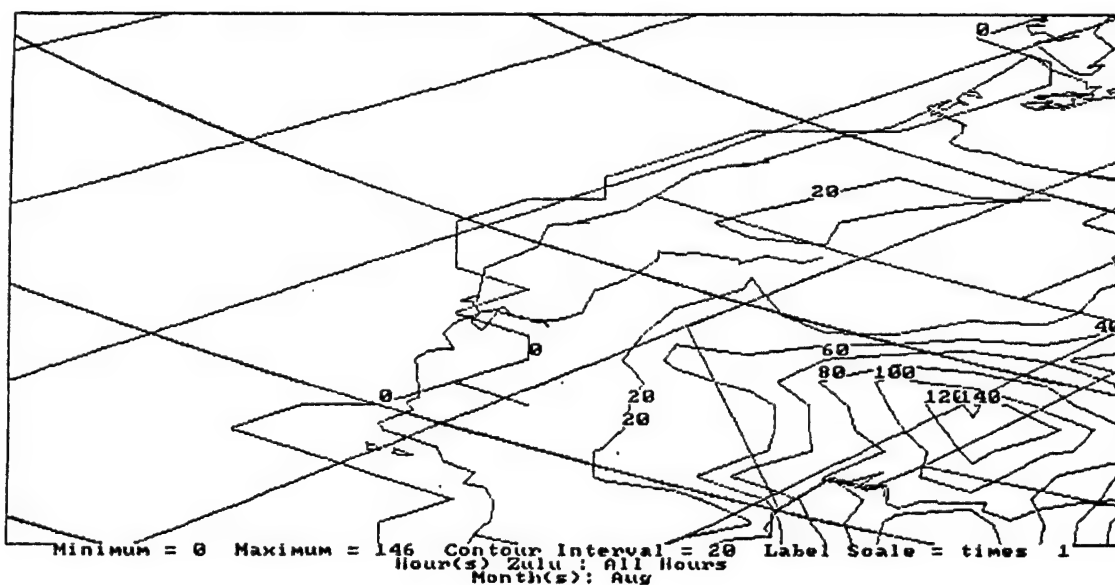
**Figure-14.** Mean Number of Thunderstorms over the CONUS during August. Source: Changery (1981).



**Figure-15.** Lightning-strike patterns over the southeast CONUS in August. Contours represent average hourly lightning strikes.



**Figure-16.** Lightning-strike patterns over the south-central CONUS in August. Contours represent average hourly lightning strikes.

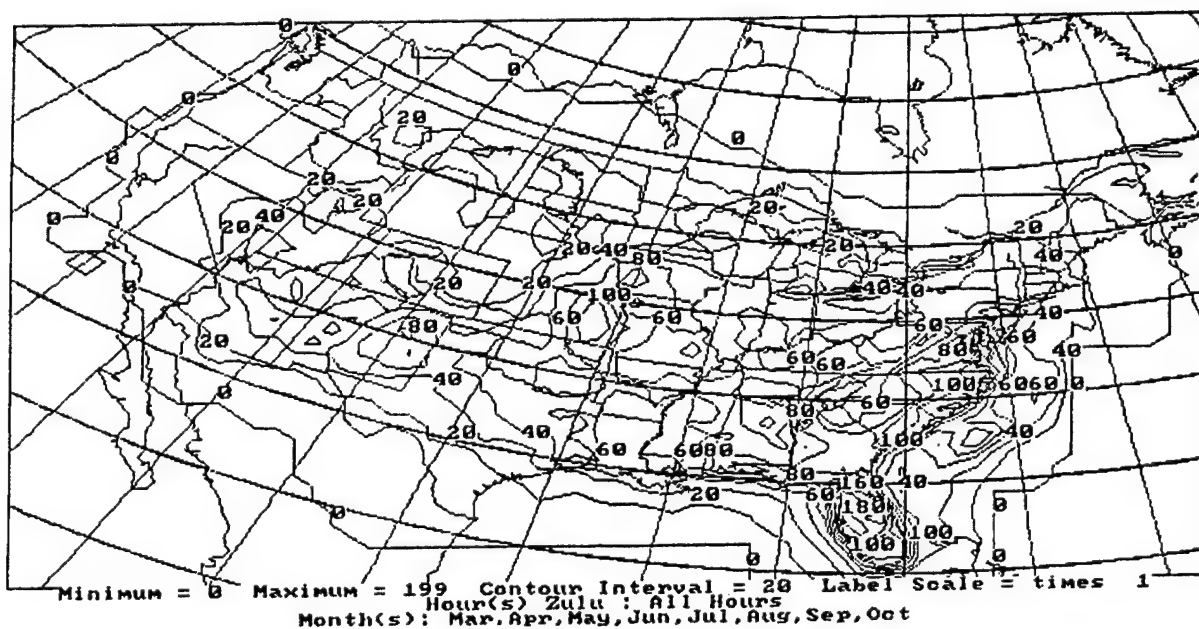


**Figure-17.** Lightning-strike patterns over the southwest CONUS in August. Contours represent average hourly lightning strikes.

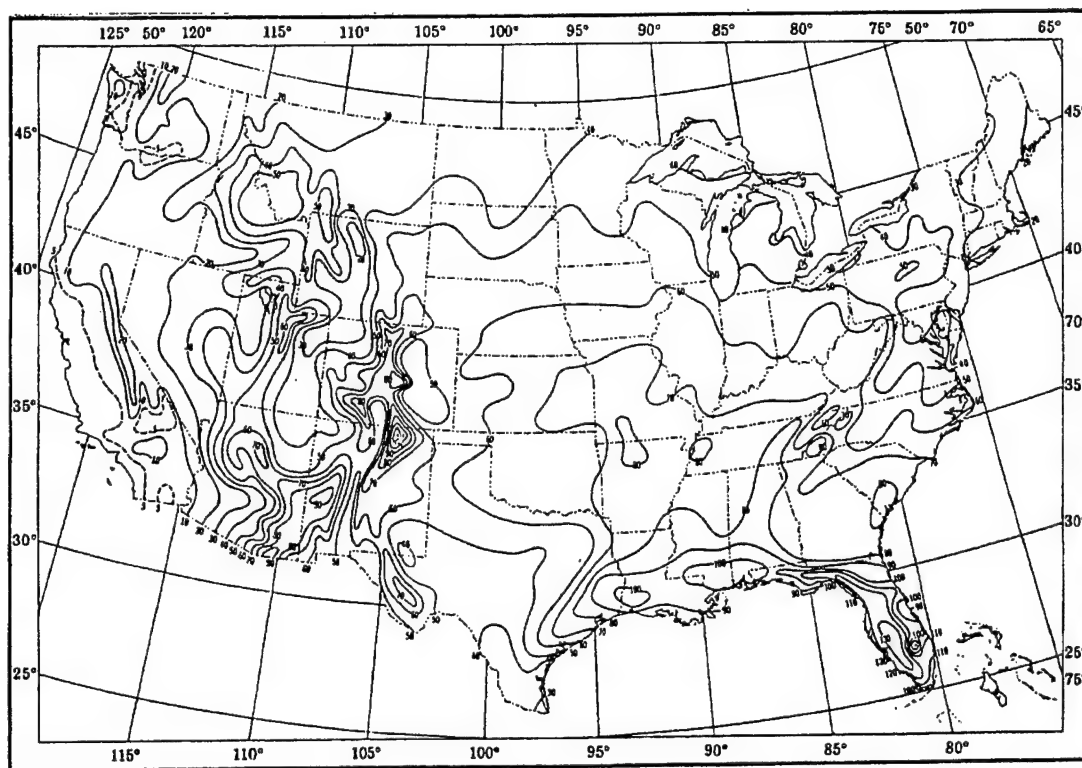
#### 4.5.4 Nationwide Lightning-Strike Patterns.

Nationwide comparisons were made between patterns in the nationwide lightning climatology (Figure-18) for all hours during March through October, the annual mean thunderstorm patterns (Figure-19) obtained by Changery (1981), and a climatology of average annual lightning strikes (Figure-20) developed by Changnon (1993). Figure-21 shows an example of the table option available in the nationwide lightning climatology. In Figure-18, a maximum value of 199 average hourly lightning strikes is evident over central Florida with secondary maximums of 100 along the Carolina coast, over the Gulf Stream, and over southwestern Iowa in the central CONUS. Also, a maximum of 80 shows well over eastern New Mexico. The overall pattern closely resembles the pattern of mean annual thunderstorms in Figure-19,

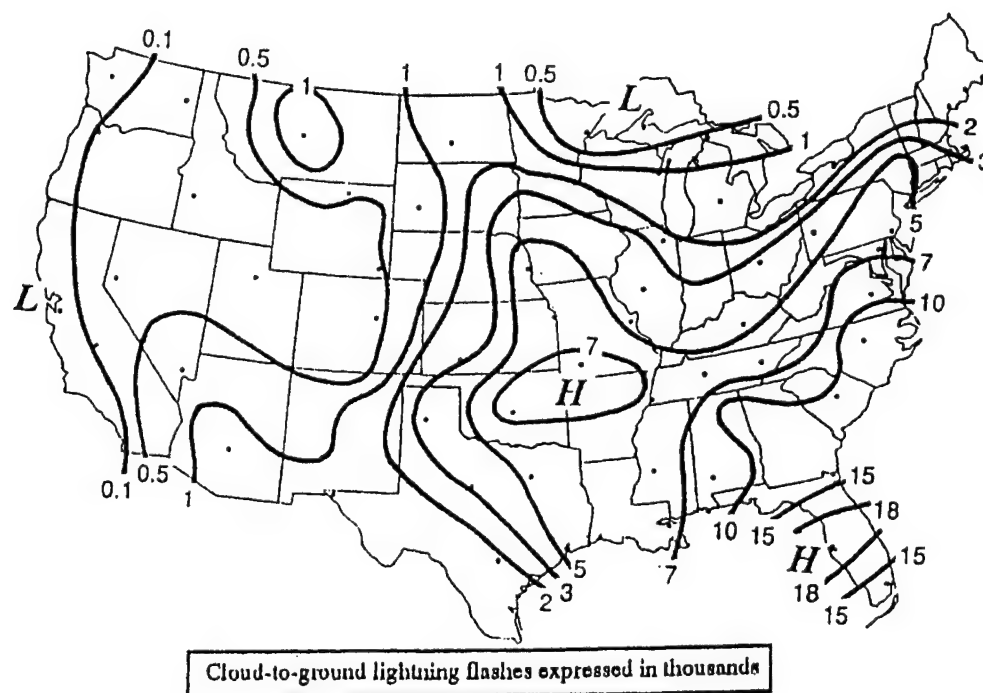
except that the concentration of average hourly lightning strikes over the central CONUS is farther north than the mean thunderstorm pattern would indicate. In Figure-20, the average annual lightning-strike pattern obtained by Changnon (1993) agrees especially well with the thunderstorm pattern in Figure-19 east of the Rockies and over most of the West, except eastern New Mexico. The pattern there is not as pronounced as in Figures-18 and -19. Perhaps that is due to the limited number of stations used. As a final example, the table of average hourly lightning strikes from the nationwide lightning climatology in Figure-21 for all hours can be used to compare lightning-strike density by region. The Southwest region stands out with the highest density, followed by the south-central and Northern Plains regions, which resembles the magnitudes of lightning-strike patterns in both Figures-18 and -20.



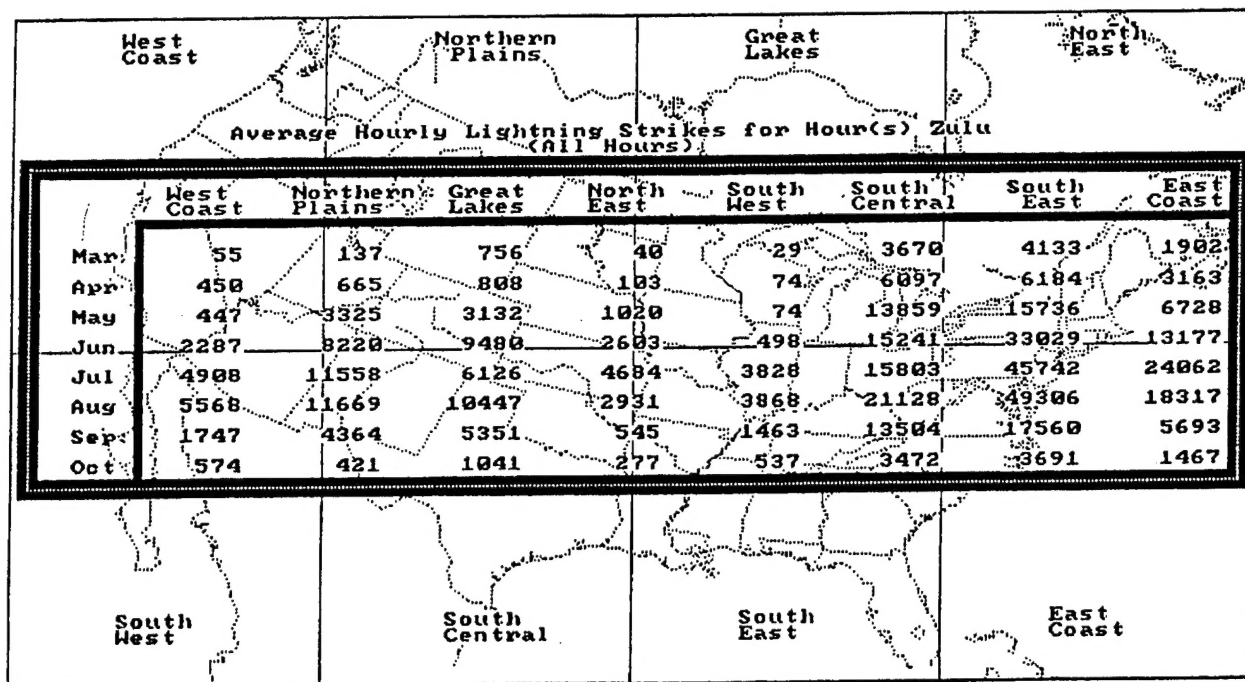
**Figure-18.** Nationwide lightning-strike patterns during March through October. Contours represent average hourly lightning strikes.



**Figure-19.** Annual mean thunderstorms over the CONUS. Source: Changery (1981).



**Figure-20.** Average annual lightning strikes over the CONUS. Source: Changnon (1993).



**Figure-21.** Average hourly lightning strikes over the area of interest by month and region.

**4.6 Overall Quality.** The nationwide lightning climatology of average hourly lightning strikes appears representative of lightning-strike patterns over the CONUS and in some areas beyond its borders. Despite limitations in detection efficiency and strike location, and marginally acceptable periods of record in some areas, it adequately depicts temporal and

spatial variations in lightning-strike patterns that compare favorably with known variations in thunderstorms. No attempt was made to adjust the climatology for detection efficiency, variations in detection efficiency, or strike location. The user should take care in comparing data in greatly separated parts of the country or on the fringes of the lightning direction finder network.

## Chapter 5

### SUMMARY

**5.1 Discussion.** The nationwide lightning climatology was developed for use as a planning tool to enhance Air Force support to acquisition customers in determining equipment test locations based on lightning-strike probabilities. It was shown by examples that the lightning climatology is consistent with known spatial and temporal variations in thunderstorm patterns. Applications of the climatology could be extended to aviation forecasting, marine operations, resource protection, and climatological studies, to name a few. The lightning

climatology undoubtedly holds much more information about lightning-strike patterns than was presented in this report.

**5.2 Recommendation.** AFCCC recommends use of the nationwide lightning climatology as another tool for planning and forecasting purposes. When used in combination with knowledge of synoptic conditions and other climatological factors, the lightning climatology has potential to improve identification of thunderstorm-prone areas.

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## GLOSSARY

AFB	Air Force Base
AFCCC	Air Force Combat Climatology Center
AFGWC	Air Force Global Weather Central
BOX	Box number in which a lightning strike occurred
BOXNUM	Grid box number
C-17	U. S. Air Force cargo aircraft
CG	Cloud-to-ground (lightning)
CONUS	Continental United States
DB2	AFCCC's relational database
EGA	Enhanced Graphics Adapters
EST	Eastern Standard Time
GDS	GeoMet Data Services, Inc.
HP	Hewlett Packard
HR	Hour
I	64th-mesh I coordinate
I <sub>4</sub>	Quarter-mesh I coordinate
IBM	International Business Machines Corp.
I JUNITS	Number of grid boxes in each whole-mesh grid box (16 for quarter-mesh)
ILAT	64th-mesh I coordinate at upper-left corner of grid system
INT	Operator that acts to keep only the whole part of a number
J	64th-mesh J coordinate
J <sub>4</sub>	Quarter-mesh J coordinate
JLON	64th-mesh J coordinate at upper-left corner of grid system
KB	Kilobyte
LATDEC	Latitude in decimal degrees
LLP	Lightning Location and Protection, Inc.
LONDEC	longitude in decimal degrees
LST	Local Standard Time
MB	Megabyte
MIN	Minutes past the hour
MS-DOS	Microsoft-Disk Operating System
NLDN	National Lightning Detection Network
PCURR	The polarity (positive or negative) of the charge lowered to ground by the first return stroke of the flash, and the peak current (in kiloamps) of the first return stroke
SQRTBOX	Square root of the total number of quarter-mesh grid boxes in a grid system
WMO	World Meteorological Organization
YR	Year
Z	Zulu (Greenwich Mean Time)